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instruction
manual

majoreg

series **440/460**

Weir Electronics Limited

DURBAN ROAD · BOGNOR REGIS · SUSSEX · ENGLAND

MP MASTER
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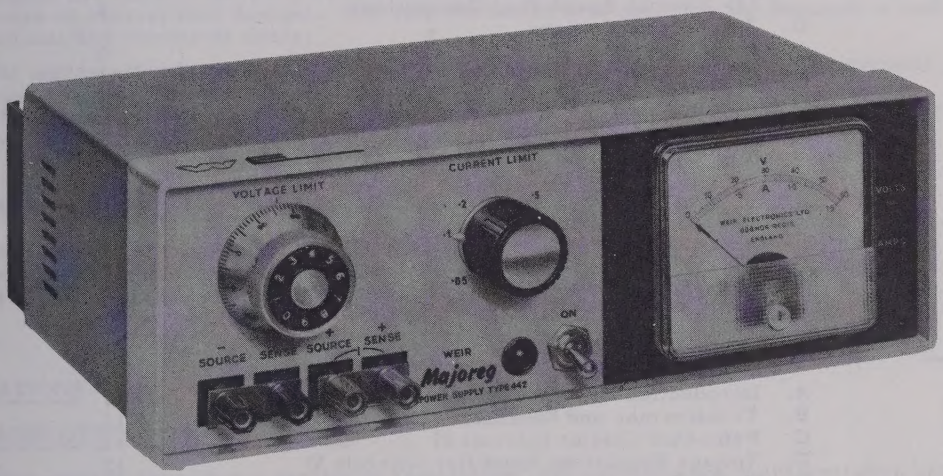

Power Supply Type 442

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1. INTRODUCTION

A. GENERAL

The Majoreg 440, 460 Series Variable Power Supplies have been designed to meet the demand for high performance, miniature regulated units, with continuous control of both current and voltage.

The maximum regulated output that can be achieved at an ambient temperature of 25°C, for the 440 and 460 series power supplies, depends on both load current and line voltage; the 440 series can achieve 40V for load currents up to 1 amp and line voltages 10% low, but under some conditions is useable up to 50V or 1·25 amps. Similarly, the 440 series supply will give 1 amp at 50V, with line voltage 10% low, and is generally useable up to 60V or 1·25 amps.

An increase in ambient temperature will tend to decrease the available output but the effect is not very great. However, at high ambient temperatures or for high currents and low voltage outputs, the rear panel heat sinks can reach 60°C and activate thermal cutouts. This is discussed further in section 4.

Although originally commissioned to meet the requirements of educational authorities, where cost and flexibility are of paramount importance, the application of value engineering techniques has enabled the cost/flexibility criteria to be met whilst attaining a performance in excess of conventional designs. The 440, 460 Series thus satisfies the demands of both educational and industrial users.

The unit is not only a regulated power supply; by a flexible combination of terminals and tag-board, it may be operated as a pulsed power source, linear d.c. power amplifier, threshold switch or temperature regulator. In addition, the unit may be remotely programmed (external resistor) and operated in series or parallel, grounded and un-grounded.

B. TYPE 441, 461 and TYPE 442, 462

Four options are available: the standard units Type 441 and 461 fitted with a nominal 1% continuously variable voltage control and the calibrated units Type 442 and 462 with a nominal 0·3% continuously variable voltage control with digital readout.

2. APPLICATIONS

A. INTRODUCTION TO APPLICATIONS

This section describes a variety of applications and performance characteristics of the Series 440, 460 Power Supply. This supply is specifically designed to be useful for a number of applications in addition to simple load voltage regulation. The Series 440, 460 Supply has many unique characteristics which give it great flexibility and permit a wide variety of applications. It is not feasible, here, to do more than discuss typical applications and performance characteristics, but by describing a cross-section of possibilities, it should be possible for the user to discover other variations suitable to his specific requirements.

B. CIRCUIT BOARD CONNECTIONS

(1) GENERAL

In order to provide flexibility for a variety of applications there are four binding posts and four quick-connect plug connections on the printed circuit board. The circuit board connections can be reached by removing the cover. They are designated Nos. A10 to A13 and the terminal number is stamped on the amplifier circuit board. The connections to the binding posts and the circuit board are indicated in the simplified schematic shown on Page 2. The circuit board connections are made to female miniature plugs on the printed circuit board which will receive test lead jacks (dia. 0·060", 0·15cm).

(2) BINDING POST CONNECTIONS

The controlled source delivers power to the − and + source binding posts. For normal internal connections the controlled source tends to maintain a constant voltage between − and + sense binding posts. The value of this constant voltage is determined by the setting of the front panel voltage control. For normal voltage regulation the + source and + sense terminals are connected together with a shorting bus and form the + output terminal, as indicated; likewise − source and − sense terminals.

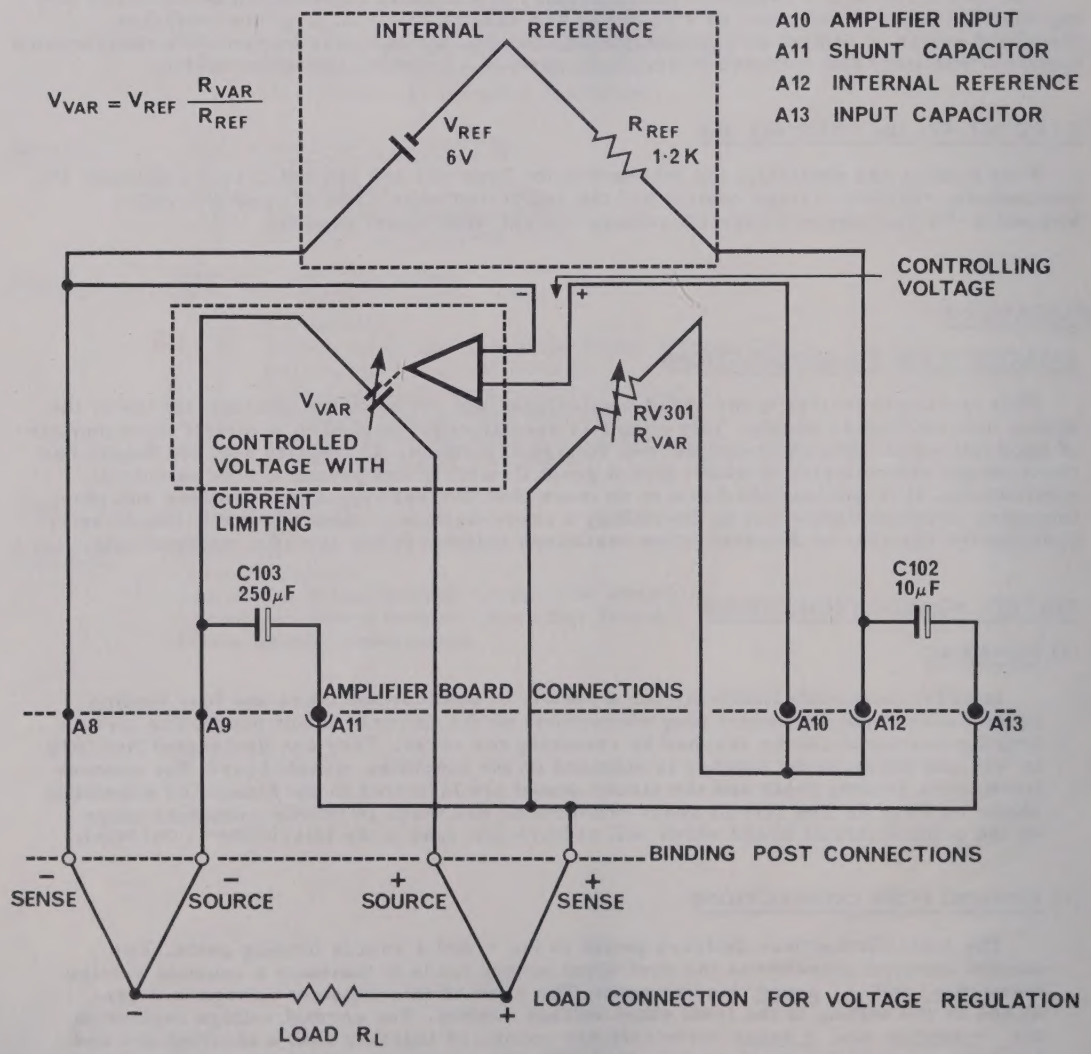
There is a current limiting circuit which limits the current from the controlled source. Current limiting will occur when the current out of the + source binding post tends to exceed the setting of the front panel current limit control.

(3) CIRCUIT BOARD PLUG CONNECTIONS

No. A11. This connects a 250μF capacitor across the output of the supply. It must be present to prevent oscillation in the supply and to provide low output impedance at high frequencies. It can be removed for fast response when operating with current limiting or when other frequency compensation is used. (See parts C4 (b), C5 (d), and C5 (g)). (White wire).

No. A10. This connection is used for remote programming. If an external voltage control is used, it should be connected in place of the internal resistor between + sense and A10 joined to A12. The regulating voltage is approximately $V = 0 \cdot 2 + 0 \cdot 005R$ (units of volts, ohms, and amps) where R is the total resistance between + sense and A10 (See part C2 (g)). (Green wire).

No. A12. This connects to the internal zener diode reference circuit, signified by the 6v battery, V_{REF}, and 1·2KΩ resistor, R_{REF}, in the diagram on Page 2. If it is desirable to use an external reference, A12 can be disconnected. (See parts C5 (b), C5 (d) and C5 (g)). (Blue wire).



Binding Post and Printed Circuit Board Connections

C. TYPICAL APPLICATIONS

(1) GENERAL

For convenience of discussion, the applications are described under the following headings:

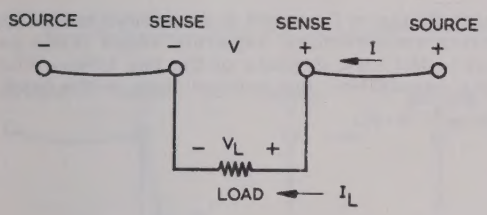
(2) Voltage Regulator Connections ; (3) Current Regulator Connections ;
(4) Temperature Regulator Connections ; (5) Power Amplifier Connections ;
(6) Series and Parallel Operation.

In the discussion, the following symbols are used:

V_S	=	setting of panel voltage control
I_S	=	setting of panel current limit control
V_X, V_Y, R_X, R_Y	=	external batteries and resistors
D_X, T_X	=	external diodes and transistors
V_L	=	load voltage
I_L	=	load current
V	=	voltage out at binding posts
I	=	current out at binding posts

(2) VOLTAGE REGULATOR CONNECTIONS

1



(a) Normal - This provides voltage regulation with current limiting. Panel meter, if present, reads V_L or $(I_L + 0{\cdot}005)$. Normal output range is:

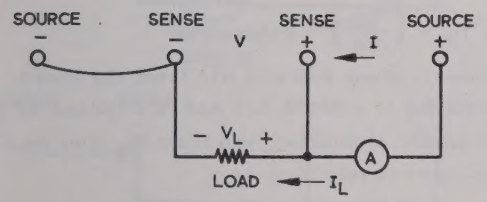
for 440 Series, $0{\cdot}2 < V_L < 50 - 10I_L$

$0 < I_L < 1{\cdot}1$

for 460 Series, $0{\cdot}2 < V_L < 60 - 10I_L$

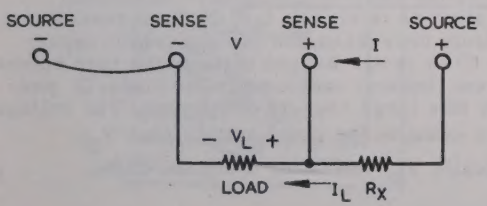
$0 < I_L < 1{\cdot}2$

2

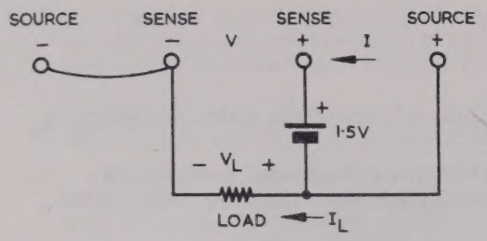


(b) External Current Metering – Ammeter, A, reads $(I_L + 0{\cdot}005)$ but the voltage drop across the meter does not affect the regulation of V_L.

3



(c) External Power Dissipation – This minimises temperature rise of the power supply. The external power resistor, R_X, dissipates power that would otherwise be dissipated internally. Typically, R_X is chosen to make $V_L + I_L R_X \simeq 40$v. A switch in series with R_X can be used for rapid turn-off of load current.



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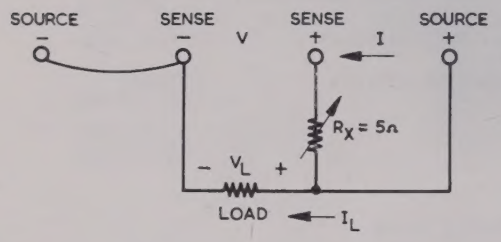
(d) Extended Range of Regulation - Normal range of regulation of supply is down to 0·2V. By the addition of the battery shown in circuit 4, V_L is 1·5V less than control setting and hence can be made zero.



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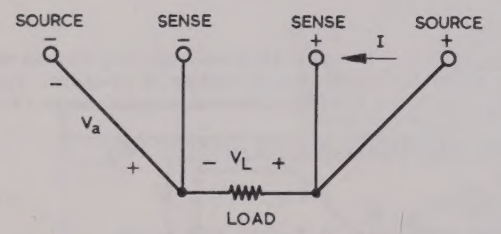
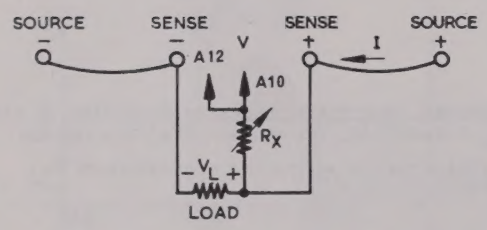
(e) Fine Voltage Control – A 25mV fine control range is achieved by R_X, but note that the high frequency output impedance is increased by up to 5Ω unless R_X is bypassed by a capacitor.



6

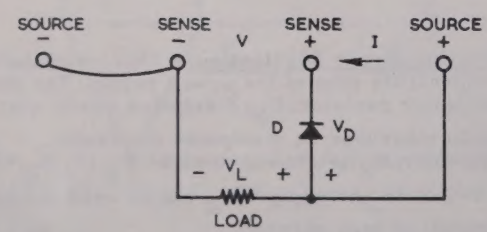
(f) Remote Sense – To avoid p.d. across power leads affecting stabilisation, separate sense leads go direct to the load in place of the two links. For proper regulation, the voltage drop in the lead, V_a, must be < 0·3v.



7

(g) Remote Programming – This allows R_X to control V_L; $V_L = \left(\frac{R_X}{200}\right) + 0{\cdot}2v$.

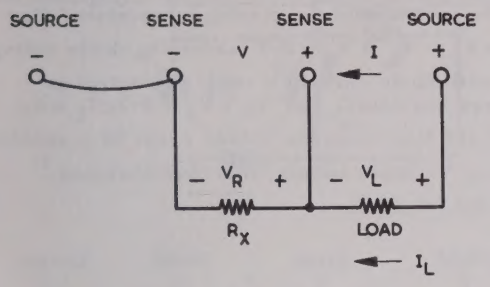
Disconnect plugs A10 and A12 from the board. Connect R_X to sockets A10 and A12 (joined by a short lead). A shielded lead from R_X may be necessary to avoid pick-up.



8

(h) High Speed Current Limiting – In normal operation as in circuit 1, if the load resistance suddenly decreases, the internal shunt capacitor, C103, is discharged through the load before current limiting can occur. The diode, D, prevents this large capacitive current. The voltage, V_L is equal to the panel setting plus V_D; Typically V_D = 0·7v for a silicon diode.

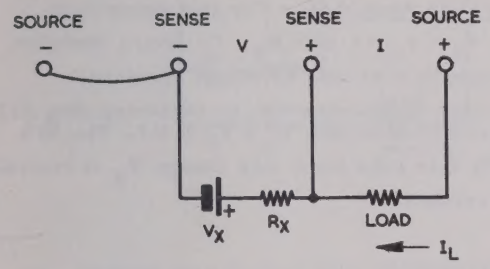
(3) CURRENT REGULATOR CONNECTIONS



1

(a) Normal – Although the supplies have current limiting, the addition of the external resistor shown in circuit 3 (1) provides for precise current regulation. When regulating,

$I_L = \left(\frac{V_S}{R_X}\right) + \cdot 005$. The panel meter reads $V_L + V_R$ or I_L. Use as large an R_X as possible for best regulation, but normally $I_L \times R_X + V_L$ should be less than 40 volts.



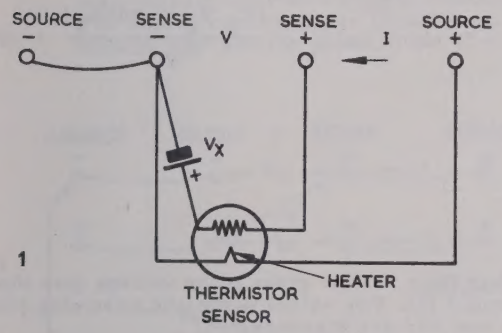
2

(b) Extended Range – This is used to extend the current regulating range to currents less than ·005 amps. When regulating,

$I_L = \cdot 005 - \left(\frac{V_X - V_S}{R_X}\right)$. For very low currents set $V_S = 0 \cdot 2$ and remove internal reference, by unplugging A12 on the circuit board; then

$I_L \simeq -\frac{(V_X - 0 \cdot 2)}{R_X} + 2 \times 10^{-5}$a.

(4) TEMPERATURE REGULATOR CONNECTIONS

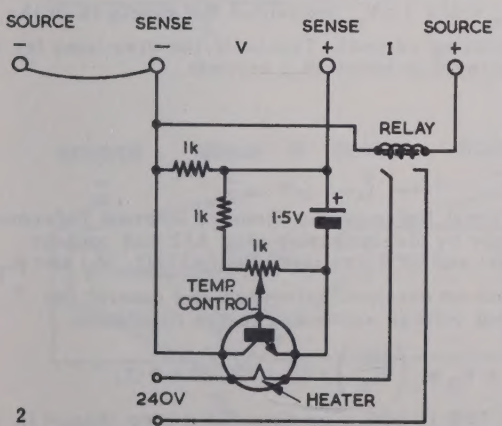


1

(a) Proportional Control with Thermistor Sensor – When regulating

$\frac{(V_X - V_S)}{(\cdot 005)}$ = (Thermistor Resistance).

Current limiter controls maximum heater current. Use a heater resistance of about 45 ohms for maximum power into heater. Typical thermistor resistance ranges from 50 ohms to 5K.



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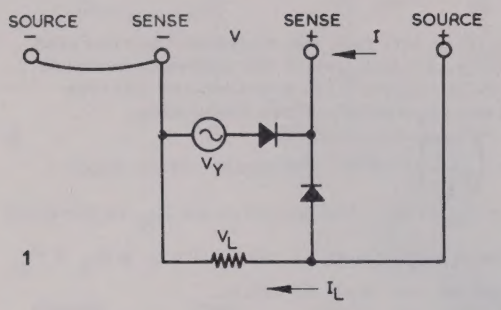
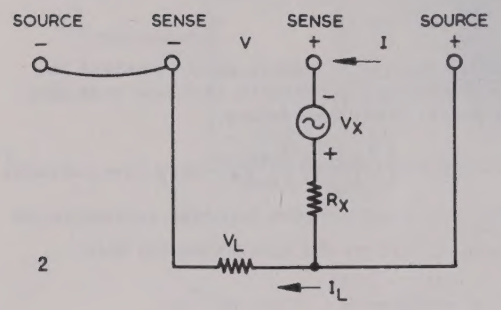
(b) On-Off Control with Transistor Sensor – Disconnect internal reference and C103 (plugs A12 and A11) and set $V_S = 0$. The transistor sensor takes advantage of the temperature dependence of the base-to-emitter voltage. This same sensor can be used for proportional control (similar to circuit 4 (1). Alternately, the power supply can be used to control an SCR or power transistor which in turn, controls the heater power.

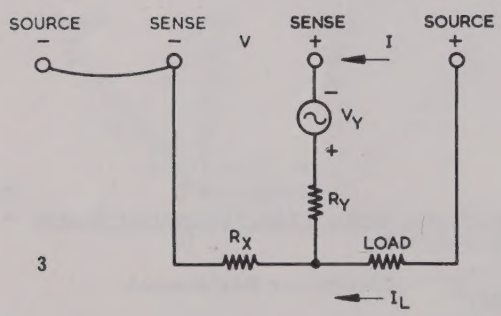
(5) POWER AMPLIFIER CONNECTIONS



(a) Pulsed Output using Diode Gating – This circuit can be very useful for testing transistors. For $V_Y < V_L$, $V_L = V_S + 0{\cdot}7$ (assuming diode voltage 0·7 with diode current = ·005) and output is voltage regulated. For $V_Y > V_S + 0{\cdot}7$, $I_L \simeq 0$. Rise and fall times for I_L are about 30 μ seconds. Source V_Y must supply 5mA plus charging current for C103.

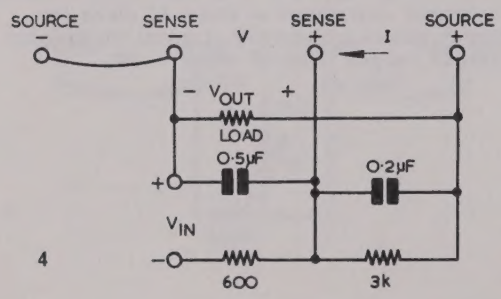


(b) Unity Gain Amplifier – For this connection $V_L = V_S + V_X + (\cdot005)\, R_X$. To insure stability, R_X must be less than 25 ohms. If internal reference is disconnected, by removing plug A12 on circuit board, then $V_L \simeq V_X + 0{\cdot}2$. The 10% to 90% rise time for a step change V_X is typically 50 μ seconds.

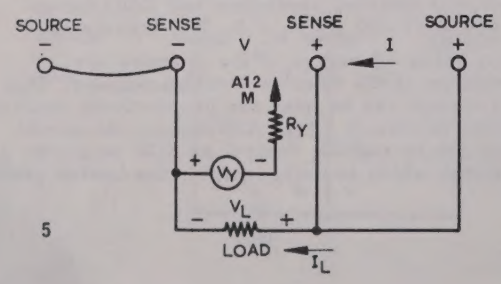


(c) High Output Impedance – A combination of circuits 3 (1) and 5 (2) used to produce a load current proportional to V_Y.

Typically, R_X = 1 ohm, R_Y = 50 ohms and $I_L = \dfrac{(V_Y\, V_S + \cdot005 R_Y)}{R_X} + \cdot005$.



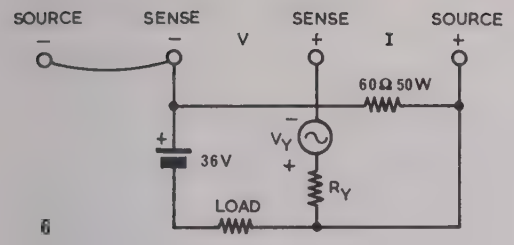
(d) Higher Gain – This gives more voltage gain than circuit 5 (2). For values given and assuming plugs A11 and A12 are disconnected, $V_{out} = 1{\cdot}2 + 5V_{in}$ (provided the supply is in the regulating region). Typically, the rise time for a step input is about 50 μ seconds.



(e) External Reference – Remove internal reference supply by disconnecting plug A12 and connect 'free' end of R_Y to this plug (A12M). V_Y and R_Y act as an external reference and control the output voltage according to the regulation

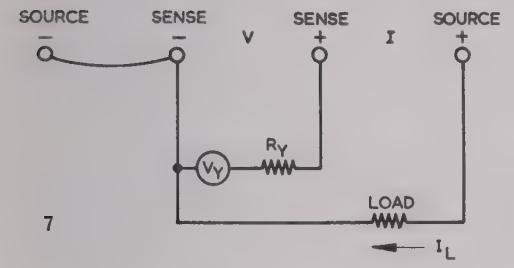
$$V_L = V_S \times \left(\frac{200}{R_Y}\right) \times (V_Y + 0{\cdot}2) + 0{\cdot}2.$$

The 10% to 90% rise time for a step change in V_Y is about 0·1 sec.



6

(f) Modification to Allow Both Polarities of Output – The 36 volt battery and 60 ohm resistor make it possible to deliver up to 2·4 watts of sinusoidal power into a 40 ohm load. Similar modifications can be made to circuits 5 (3) and 5 (4).



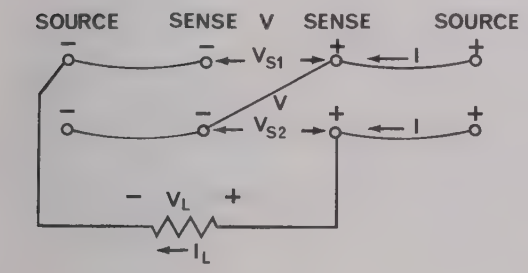
7

(g) Threshold Amplifier – Disconnect internal reference and capacitor C103 by removing plugs A11 and A12 on circuit board, and set $V_S = 0$. Then $I_L = 0$ for $V_Y > 0{\cdot}2$ and $I_L = I_S$ for $V_Y < 0{\cdot}2$. Response time is about 20 μ sec. max.

(6) SERIES AND PARALLEL OPERATION

(a) GENERAL

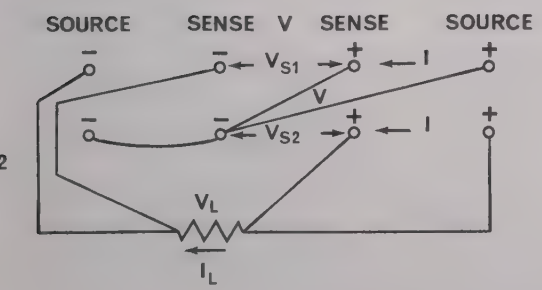
Units may be used directly in series or parallel without damage to the power supplies. For parallel operation it is difficult to achieve current sharing, but if the output voltages are set equal the regulation will normally be satisfactory. One unit will supply all of the load current until it limits and then the other unit will begin to contribute load current. For series operation one should keep in mind the 200 volt maximum rating between any binding post and the case.



1

(b) Separately-set Series Supplies with Local Sensing – The most usual arrangement.

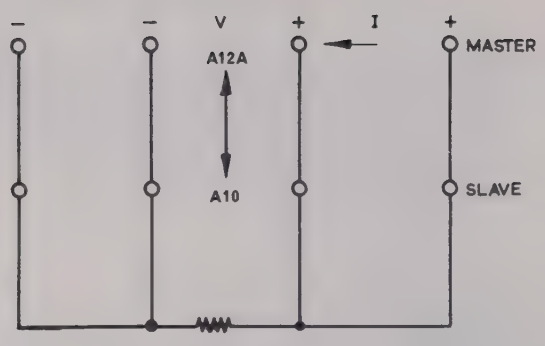
$V_L = V_{S1} + V_{S2}$ so long as neither supply is current limiting. If either supply is current limiting then I_L is current limited to the lowest current limit.



2

(c) Separately-set Series Supplies with Remote Sensing –

$V_L = V_{S1} + V_{S2}$ as in (6b). Since not more than 0·3v may exist between – source and – sense terminals, they must be linked at the common point of the two supplies.



(d) Auto-Parallel Operation – One supply will tend to take most of the load, but as it warms up its voltage will drop slightly and the load will shift to the other unit. A12A means connect to A12 without removing internal connection to A12. A10 should be connected in lieu of internal connection.

3

3. PRINCIPLES OF OPERATION

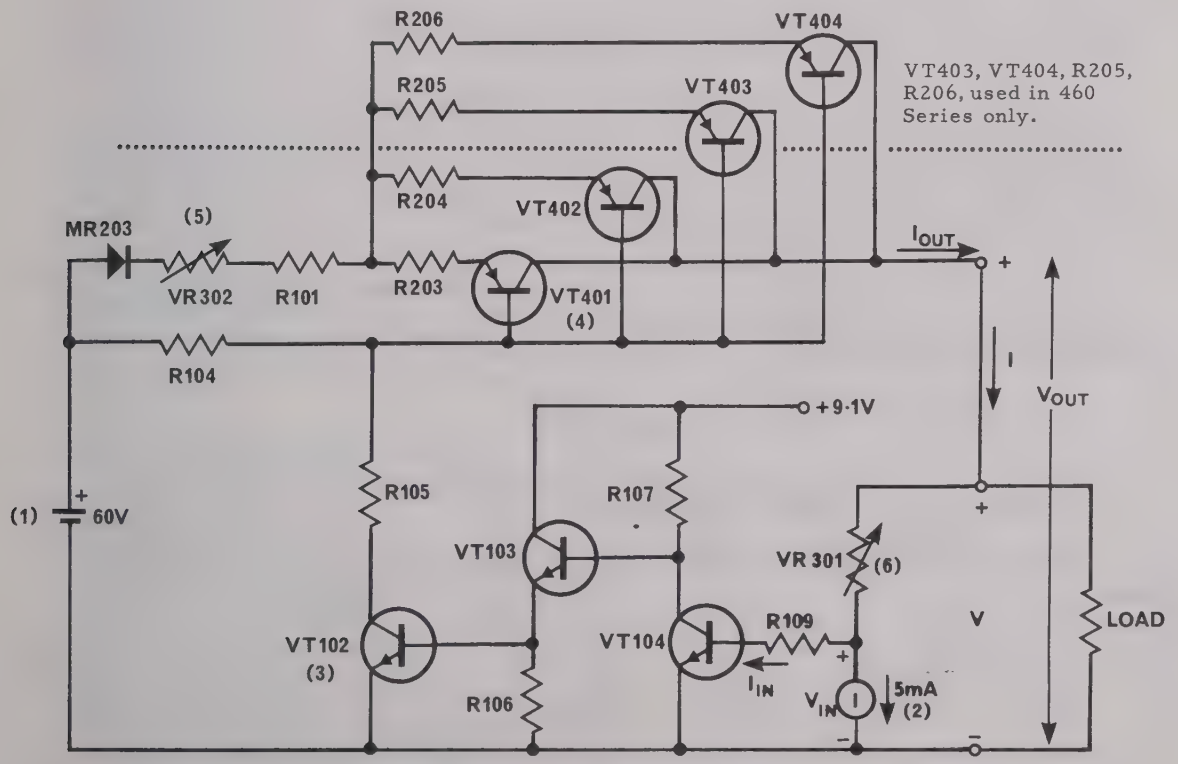
A. INTRODUCTION

This chapter describes the operation of the power supply circuit and the function of the various circuit components. The explanation is primarily qualitative and does not require an extensive mathematical background on the part of the reader.

There are two basic modes of operation for the power supply. The most important is the voltage regulating mode in which the voltage between + sense and − sense is held extremely constant at a value determined by the front panel voltage control potentiometer. The second mode is the current limiting mode in which the current out of the + source terminal is limited to a value determined by the front panel limit potentiometer. These two modes are more or less independent of how the power supply is used so we assume, for this chapter, that the power supply is connected in the normal manner for load voltage regulation (see part 2C(2)(a)). In this section the overall operation for each of the two modes is explained, and then the operation of six sub-circuits is considered in more detail.

B. THE VOLTAGE REGULATING MODE

The diagram below shows a simplified schematic for the power supply when it is operating in the voltage regulating mode. Six functionally distinct parts of the circuit are designated 1 through 6 and this designation will be adhered to for the rest of this book. Circuit part 1 is represented as a 60 volt battery though, in fact, it is a rectifier circuit which converts the power line 240 volts, say, 50Hz into about 60 volts dc. Likewise, 2 is designated as a 5 milliamp current source though it is actually a very constant voltage source in series with a resistance adjusted to produce 5 milliamps of current as indicated. The current in the base of transistor VT104 is so small that the current through VR301, 6, is also very nearly equal to 5 milliamps. The regulation is accomplished by a three stage amplifier, 3, driving power transistors, 4, which are in series with the load. R203, R204 are to ensure sharing of the output current in the series transistors. In the voltage regulating mode we can effectively replace the current limiting circuit, 5, by three resistors, one of which is the current limit control VR302. This circuit simplification is possible because the diode and the transistor in circuit 5 conduct negligible current when in the voltage regulating mode.



Simplified Schematic in Voltage Regulating Mode

In order to gain a physical appreciation for the operation in the voltage regulating mode, it is useful to study the effects of a change in line voltage or load current. Assume, for example, that there is an increase in line voltage or a decrease in load current so that V_{out} tends to increase. With reference to the figure, note that any increase in V_{out} will cause an increase in V_{in} which will cause the first amplifier transistor, VT104, to conduct more and transistors VT103, VT102 to conduct less. The net effect is to decrease the current in the power transistor, VT401, and thereby reduce the tendency for V_{out} to increase. In actual operation it takes only about a one millivolt change in V_{in} to switch the power transistor from full-on to full-off or vice-versa.

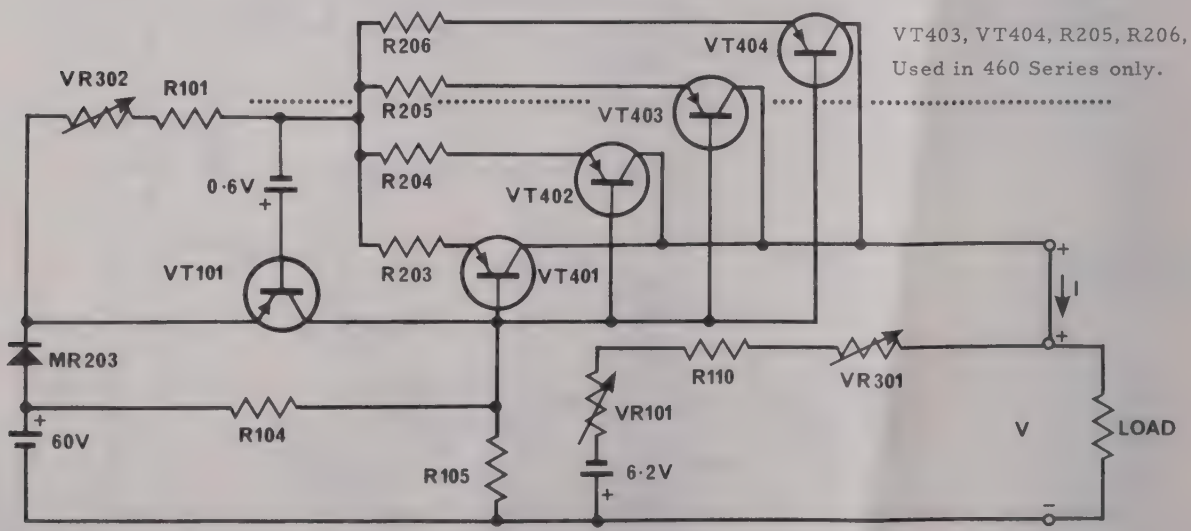
C. THE CURRENT LIMITING MODE

In this mode the power supply attempts to maintain a constant current through the power transistors, VT401, VT402, VT403, VT404. For this discussion assume that the load is connected as shown in the diagram below with a sufficiently low load resistance to cause current limiting (i.e. the load voltage is less than the setting of the voltage control).

The diagram below shows a simplified schematic for the power supply when it is operating in the current limiting mode. The six parts of the circuit have a different appearance than in the previous diagram because the transistors and diodes are in different states. Note particularly that VT104 is cut off (i.e. negligible currents in the emitter, base and collector), VT102 is saturated (i.e. practically a short circuit between emitter, base and collector) and VT101 is acting as an amplifier. The 0·6 volt battery is actually a forward biased diode which acts as a voltage reference.

The operation of the current limiting circuit has a considerable resemblance to the operation of the voltage regulating circuit. Assume, for example, that there is an increase in line voltage or a decrease in load voltage. With reference to the diagram note that either of these changes would tend to produce an increase in load current, I_{out}. Any increase in I_{out} produces an almost equal increase in current through VR302 which, in turn, tends to increase the collector current in VT101. The net effect is to decrease the base current in the power transistors VT401, VT402, VT403, VT404, and thereby reduce the tendency for I_{out} to increase. In actual operation there is less than a 10 millivolt increase in voltage across $(R101 + R_A)$ as V_{out} decreases to 0 volts or as V_{line} increases from 230 to 250 volts. Thus, to a first approximation, I_{out} = constant in the current limiting mode.

The output current is very nearly constant for all operation in the current limit mode but, of course, is subject to some variation due to changes in line voltage, load voltage, or temperature. These variations in I_{out} are much larger than they would be if the power supply were connected for current regulation (see part 2C (3)(6). I_{out} is sufficiently constant, however, to prevent damage to the power supply and to minimise the possibility of damage to the load circuit.



Simplified Schematic in Current Limiting Mode

4. THE SIX SUB-CIRCUITS

A. INTRODUCTION

This section contains a more detailed description of the operation of each of the circuit parts, designated 1 through 6, in the diagram of part 3. A complete schematic is shown in the circuit diagram of part 6 with the sub-circuits separated by dotted lines. Most of the discussion in this section refers to this complete schematic. The physical appearance and location of the various components can be identified in the printed circuit layout diagrams in 6.

B. TRANSFORMER AND RECTIFIER FILTER (CIRCUIT 1)

The mains transformer TR3A provides secondary e.m.f.s of 53-44-26·5-0-44-53 volts. A half-wave rectifier MR204 and filter capacitor C201 converts the 26·5 secondary volts to a smoothed output of about −24 volts, with a 50Hz ripple of about two volts peak-to-peak. This negative rail is used by the Current Reference Circuit (2). A full wave rectifier, using MR201 and MR202, driven from the two 53 volt secondaries, provides a nominal +60 volt output across filter capacitor C303. This positive rail is used by the Voltage Regulating Amplifier (3) and also provides the power supply output current.

The rectifier output voltage and ripple voltage depend on the line voltage, the load current, and the transformer temperature. For example, in the 460 series supplies, the voltage across C303 can be as high as 79 volts for V_{line} = +5% and I_L = 0 with the transformer cool or as low as 56 volts for V_{line} = −10% and I_L = 1 amp at 60°C.

The a.c. ripple superimposed on the d.c. voltage will also vary considerably in amplitude, but it has a maximum value of 6 volts peak-to-peak at maximum output current, and a minimum of less than 0·5 volts in both at I_L = 0. It is of sawtooth form, and at 100Hz.

Another diode MR203 is in series with the output and provides about 0·6 volt bias for the power transistor circuit. Note that MR201, MR202, MR203 (and MR206) are all high current diodes mounted on the right hand rectifier printed circuit panel, as are the two wire wound resistors R301, R302. These get quite hot in operation at high output currents, and are so placed as not to overheat more temperature sensitive parts of the circuits.

MR204 is a low current diode mounted on the rectifier printed circuit board, and is protected from surges of current into C201 by R210 which also provides some smoothing. MR201 and MR202 are protected from voltage spikes out of the transformer by C202, C301 and C302.

The thermal cutouts TS4A to TS4D are mounted on the rear panel heat sink. One or more open if the heat sink temperature exceeds about 60°C, and reclose when the temperature drops to about 54°C. These cutouts prevent excessive self-heating which could cause damage to the supply. Without any self-heating all components can safely withstand 85°C. The neon pilot lamp LP301 indicates when ac is applied to the transformer and will thus signal operation of the thermal cutout. If excessive temperature limits the output of the supply, note that an external power resistor can be used to greatly reduce self-heating (see part 2C (2)circuit 3). Alternatively, an external fan can be used to reduce the temperature rise of the heat sink. The switch, S3A, is the panel on-off switch. The fuse in series with this switch is mounted on the rear panel. It protects most of the components in the power supply against excessive line voltage or against failure of some one component in the circuit. The fuse will normally burn out only if some component in the power supply fails or if improper internal connections are made.

C. REFERENCE CIRCUIT (CIRCUIT 2)

A stable reference voltage is derived from the −24 volt supply by a cascade of two regulator circuits. The first circuit consists of R111, R112, MR105 and VT105 and causes I_{C1} (the collector current of VT105) to be very nearly constant and independent of line voltage and temperature. To a fair approximation,

$$I_{C1} = \frac{(V_{Z1} - 0{\cdot}6)}{R_5} = 12{\cdot}5\text{mA}$$

(V_{Z1} is the resulting voltage of zener diode, MR105, and 0·6 is the approximate base-to-emitter voltage of the silicon transistor, VT105.)

Although I_{C1} is relatively constant it is, nevertheless, subject to variations of the order of ±0·1% with line voltage changes of ±10% or temperature changes of ±2°C. To provide better regulation, a second zener diode, MR103 is used to reduce variations even further. The voltage across MR103 is 6·2 volts ±5% and is virtually independent of line voltage or load current (i.e. ±0·001% for ±10% change in line voltage or 1 amp change in load current). The voltage across MR103 has a temperature coefficient of about +2 to +3 millivolts per °C change in temperature, which tends to partially compensate for temperature effects in VT104. The 50 cps component of voltage across MR103 is less than 50 microvolts peak-to-peak.

Resistance R110 is a low-drift temperature compensated resistor. VR101 is a small wirewound trimmer resistor, (mounted on the printed circuit board) which is used to calibrate the voltage control. The calibration control is necessary because of the unit-to-unit variations in zener voltage of MR103 and in resistors R110 and VR301. When the supply is properly calibrated and operating in the voltage regulating mode, the current through VR301 is 5ma ±3% and varies less than ±·02% with a ±10% change in line voltage, a 1 amp change in load current or a ±1°C change in temperature.

D. VOLTAGE REGULATING AMPLIFIER (CIRCUIT 3)

This is a three-stage amplifier employing a common emitter stage, VT104, driving a common collector stage, VT103, which drives a second common emitter stage, VT102. Resistor R109 is used to limit input current to a safe value under the worst case condition of VR301 = 0 and a +60 volt source connected across the output. Resistor R105 limits the current in VT102 when the circuit is operating in the current limiting mode with VT102 saturated.

A resistor, R103, and a zener diode, MR102, are used to create a constant +9 volt supply which provides power for the first two stages. The zener diode is necessary to prevent changes in voltage across C303 from producing changes in the operating point of VT104 which would, in turn, produce changes in power supply output voltage. R103 also limits the current in VT103 when the power supply is in the current limiting mode.

Note that the negative "sense" lead connects directly from the (− sense) binding post to the emitter of VT104 and the positive side of MR103. This sense lead establishes a zero-voltage reference at the (− sense) binding post and prevents internal lead resistance between circuit board and binding post from adversely affecting regulation. This internal lead resistance is typically 8 milliohms and would decrease the load regulation by about a factor of two. As described in part 2, the negative sense lead can also be connected directly to a remote load terminal in order to negate any deterioration of regulation caused by external lead resistance. However, for proper operation of the regulating amplifier, the voltage of this negative sense lead should not differ from the (−) binding post voltage by more than about ±0·3 volts.

R108 and C101 provide high frequency feed-back within the regulating amplifier. This helps prevent oscillations that would otherwise be caused by the large amount of overall feed-back through C102.

E. SERIES REGULATOR AND METER (CIRCUIT 4)

In the 440 series supplies the series regulator consists of two current sharing germanium transistors connected in series with the rectifier output and the + source binding post. In the 460 series supplies there are four transistors sharing the output current. The base currents are controlled by either circuit 3 or circuit 5. These transistors behave, essentially, as an electronically controlled variable resistor. Since they must dissipate several watts of power, they are power transistors and are mounted on heat sinks at the rear of the supply. These heat sinks are convection cooled (i.e. the heated air rises and cooler air flows in from the bottom).

The maximum possible individual transistor dissipation of 32 watts occurs in the 440 series supply under conditions of lowest output voltage and highest output current, for example, those associated with a short circuited output.

The transistors can safely dissipate this amount of power with a collector junction temperature of 92°C, a heat sink temperature of 60°C and an ambient temperature of 20°C. For operation at higher ambient temperatures, however, the transistors would be damaged by excessive junction temperatures so thermal cutouts are used as described in part 5B. Normally the thermal cutouts will not operate. For example, under maximum power output conditions of V_L = 50 volts and I_L = 1 amp(in the 460 series supplies) the ambient temperature can be as high as 40°C without causing the thermal cutouts to operate.

Diode MR206 serves a purely protective purpose and is normally reverse biased. If, however, a reverse polarity voltage is connected across the output of the power supply, then this diode will conduct and prevent damage to transistors VT104 and VT401, and capacitors C103 and C102. This type of reverse voltage situation will commonly arise if two or more

power supplies are connected in series to provide higher output voltage than can be achieved with a single supply. If one series supply is off and another one on, then the on supply load current flows through the load and through MR206 in the off supply; without MR206 the output terminals would be reverse biased.

The meter is either connected in parallel with R207 to measure current, or in series with R209 to measure voltage. Note that when switch S3B is in the current metering position and the power supply is in the voltage regulating mode, the ammeter reads 5ma more than the actual load current because of the 5ma current in VR301. This 5ma produces a discernible but negligible deflection on the meter. Note also that when S3B is in the voltage metering position, if there is external current metering or heat limiting (see part 2C (2)(b) or (c)), then the meter will not read the true load voltage.

F. CURRENT LIMITING AMPLIFIER (CIRCUIT 5)

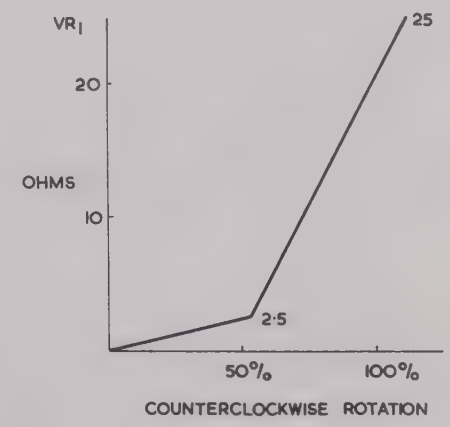
Current limiting is accomplished by a single transistor, VT101, driving the same series regulator transistors which are used for voltage regulation. The properties of VT101 and MR101 are such that the voltage across VR302 + R101 is approximately (0·85 − 0·005T) volts where T is the temperature, in °C, of VT101 and MR101. Assuming that I_{out} is approximately equal to the current through VR302 + R101 we have:

$$I_{out} \simeq \frac{\cdot 85 - \cdot 005T}{R101 + VR302}$$

The temperature dependence indicated in the above equation also decreases the maximum output current at high temperature and affords extra protection against excess dissipation in VT401, VT402, VT403, VT404.

The current limiting control, VR302, is a wirewound rheostat with a non-linear resistance vs. rotation characteristic as shown in the diagram opposite. This non-linear characteristic allows a wide range of control over the current limiting, as indicated by the panel calibration.

Resistor R104 allows the bases of VT401 to VT404 to be reverse biased for operation at high temperatures. It also helps to turn off VT401 to VT404 more quickly if the load current is suddenly reduced.



Non-linear Rotation vs. Resistance Current for R_A

G. FEEDBACK CIRCUIT (CIRCUIT 6)

The input voltage to VT104 is very nearly constant with $V_{in} \simeq 0{\cdot}2$ volts. Also, I_{in} is less than 20 microamps when the supply is in the regulating mode. Thus virtually the only current in the voltage control, VR301, is the 5ma from the reference current source. It should be evident from the circuit diagram of section 7 that if we neglect I_{in} we can use Kirchoff's laws * to write:

$$V_{out} = V_{in} + (\cdot 005 \times VR301) = 0{\cdot}2 + \frac{VR301}{200}$$

(V measured in volts and VR301 in ohms)

The above equation suggests that V_{out} will increase 1 volt for every 200 ohms increase

---

* Kirchoff's Laws state that the sum of the currents entering a junction is zero and the sum of the voltages around any loop is zero.

in VR301 and will have a minimum value of 0·2 volts for VR301 = 0. Since VR301 has a resistance which is almost exactly proportional to angle of rotation we expect V_{out} to increase uniformly with the rotation of the voltage control. This fact is borne out by the uniform spacing of the panel voltage calibrations. The front panel markings should be accurate to within ±1% of full scale (i.e. ±0·6 volts) which is actually a higher accuracy than most panel meters.

Capacitor C102 serves two important functions. Primarily it maintains a low output impedance at high frequencies, where the regulating circuit becomes ineffective, and it helps to prevent voltage transients when the load is suddenly removed. For example, the power transistor requires about 20 microseconds to turn off and C102 absorbs the power transistor current during this period of time. C102 also helps to prevent high frequency oscillation in the regulating circuit.

Capacitor C102 provides increased feedback for frequencies above about 30 cps and thereby reduces the ac output impedance and the 50 and 100 cps ripple and noise in the output.

5. SPECIFICATION

Output:	40 to 50 volts for 440/460 series to 1 amp. to 40 watts at 40°C (441/442) to 50 watts at 40°C (461/462)
Input:	240V A.C. 220V A.C. } +5 −10% 50 to 60Hz 110V A.C.
Regulation - Line: Load:	<1mv + 0·03% for 10% A.C. change <− (2mv + 0·05%) zero to full load
Ripple:	<200μv peak-to-peak
Response to Change in Load:	Recovers to within 50mv in 50μsec.
Temperature Coefficient:	<3mv + 0·02%/°C
Internal Impedance:	<10 milliohms at 1kHz.
Size:	$11\frac{1}{2}$" x 4" x $9\frac{3}{4}$" (32 x 10 x 25cm)
Weight:	$12\frac{1}{2}$lb (5·7kg)

Continuous current limit 0·04 - 1 amp (0 − 0·04 amps by external circuit)

1% calibrated voltage control 0·2 to 60 volts (0 − 0·2 volts by external circuit) (0·3% voltage control types 442/462 only).

Convection cooled with thermal cutout.

6. PARTS LIST

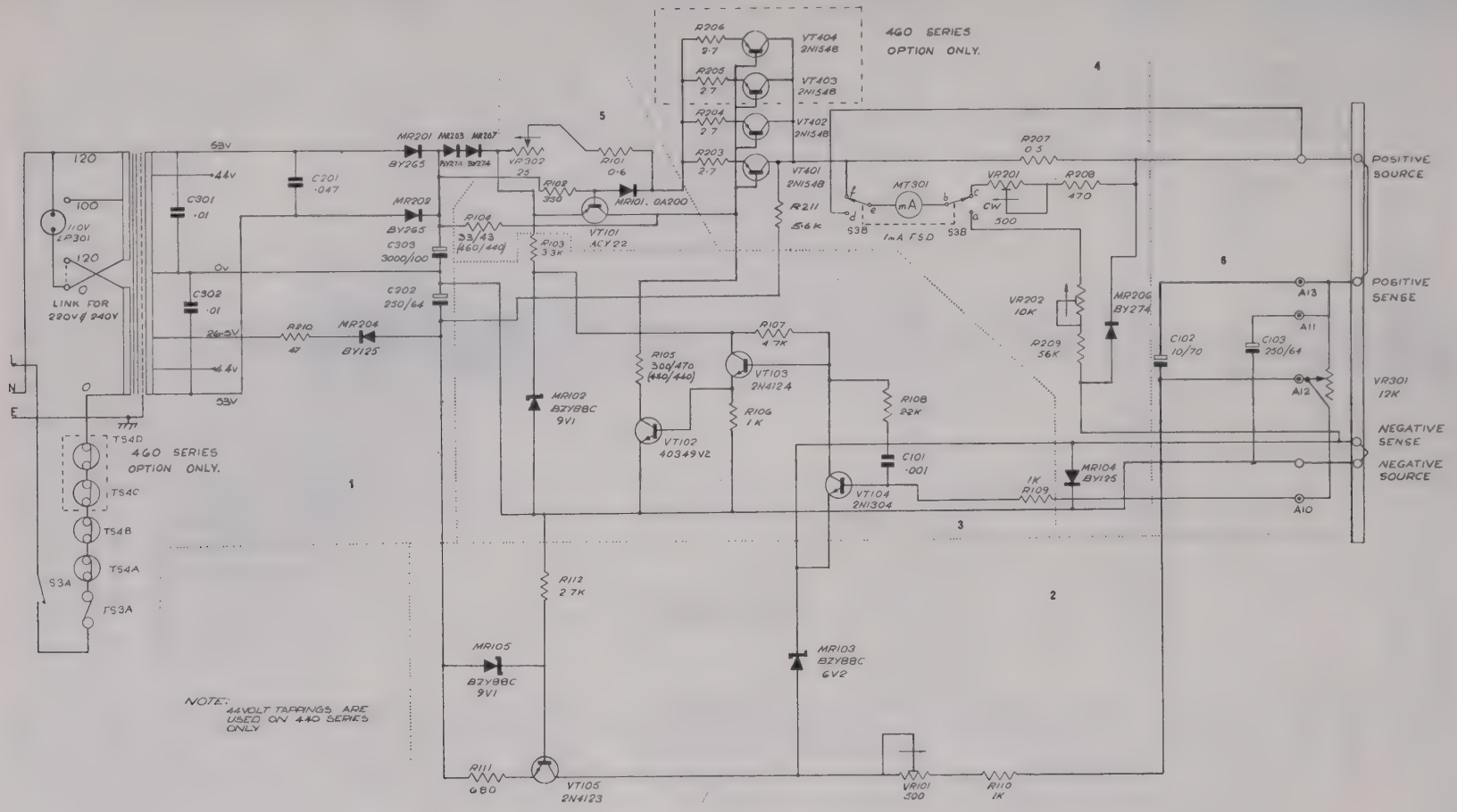
The following list includes all replacement parts with circuit references, values and tolerances where applicable, and part numbers. When ordering, please quote the NAME, TYPE and SERIAL NUMBER of the instrument, together with the CIRCUIT REFERENCE and the DESCRIPTION of PART.

Circuit Ref.	Description	Value	Rating	Tol.	Part No.
VT101	Transistor				Mullard ACY22
VT102	Transistor				R.C.A. 40349
VT103	Transistor				Motorola 2N4123
VT104	Transistor				Cosem 2N1304
VT105	Transistor				Motorola 2N4123
VT401	Transistor				Motorola 2N1548
VT402	Transistor				Motorola 2N1548
VT403 **	Transistor				Motorola 2N1548
VT404 **	Transistor				Motorola 2N1548

Circuit Ref.	Description	Value	Rating	Tol.	Part No.
MR101	Diode				Mullard OA200
MR102	Zener Diode	9·1v			Mullard BZY88C9V1
MR103	Zener Diode	6·2v			Mullard BZY88C6V2
MR104	Diode				Thorn-A.E.I. BY125
MR105	Zener Diode	9·1v			Mullard BZY88C9V1
MR201	Diode	370v	1·2A		Iskra BY265
MR202	Diode	370v	1·2A		Iskra BY265
MR203	Diode	125v	3A		Iskra BY274
MR204	Diode				Thorn-A.E.I. BY125
MR205	Diode	125v	3A		Iskra BY274
R101	Resistor WW	0·6	1W	1%	Welwyn AW3214
R102	Resistor HS	330	0·5W	5%	Iskra UPM
R103	Resistor HS	3·3K	2W	5%	Iskra UPM
R104 *	Resistor HS	130	0·5W	5%	Iskra UPM
R104 **	Resistor HS	75	0·5W	5%	Iskra UPM
R105 *	Resistor WW	820	12W	5%	C.G.S. VPF14
R105 **	Resistor WW	1K	12W	5%	C.G.S. VPF14
R106	Resistor HS	1K	0·5W	5%	Iskra UPM
R107	Resistor HS	4·7K	0·5W	5%	Iskra UPM
R108	Resistor HS	10K	0·5W	5%	Iskra UPM
R109	Resistor HS	1K	1W	5%	Iskra UPM
R110	Resistor HS	1K		1%	Electrosil TR5
R111	Resistor HS	680	0·5W	5%	Iskra UPM
R112	Resistor HS	2·7K	0·5W	5%	Iskra UPM
R203	Resistor WW	2·7	3W	5%	Radiospares
R204	Resistor WW	2·7	3W	5%	Radiospares
R205 **	Resistor WW	2·7	3W	5%	Radiospares
R206 **	Resistor WW	2·7	3W	5%	Radiospares
R207	Resistor WW	0·5	3W	5%	Radio Resistor Co. LG716
R208	Resistor HS	470	0·5W	5%	Iskra UPM
R209	Resistor HS	56K		1%	Electrosil TR5
R210	Resistor HS	47	0·5W	5%	Iskra UPM
VR101	Var.Res. WW	500			Welwyn P25
VR201	Var.Res. CF	500	0·5W	10%	Iskra PN10B
VR202	Var.Res. CF	10K	0·5W	10%	Iskra PN10B
VR301 +	Var.Res.	12K		5%	A.B.Metals 58
VR301 ++	Var.Res.(6 turn)	12K (Lin 0·25%)		3%	Beckman A
VR302	Var.Res.	25 (special law)			Colvern CLR3047-9S
C101	Capacitor	0·001	500V		Hunts SLM32
C102	Capacitor	10	70V		Hunts AW1811A00
C103	Capacitor	250	64V		Mullard C437/AR/H250
C201	Capacitor	0·047	250V		Hunts SLM55
C202	Capacitor	250	64V		Mullard C437/AR/H250
C301	Capacitor	0·01	250V		Hunts SLM13
C302	Capacitor	0·01	250V		Hunts SLM13
C303	Capacitor	3000	100V		Sprague 36D302 F100BC2A
TR3A	Transformer				Weir B5035/29
S3A	Switch				Arrow 8040/BT13
S3B	Switch				Arcolectric T225
TS4A	Thermal Cutout				Weir A5024/24
TS4B	Thermal Cutout				Weir A5024/24
TS4C **	Thermal Cutout				Weir A5024/24
TS4D **	Thermal Cutout				Weir A5024/24
LP301	Lamp Neon	110V			Arcolectric SL268
FS3A	Fuse Link	5A (20mm)			
MT301	Meter 0-1mA				Eagle MR-3P

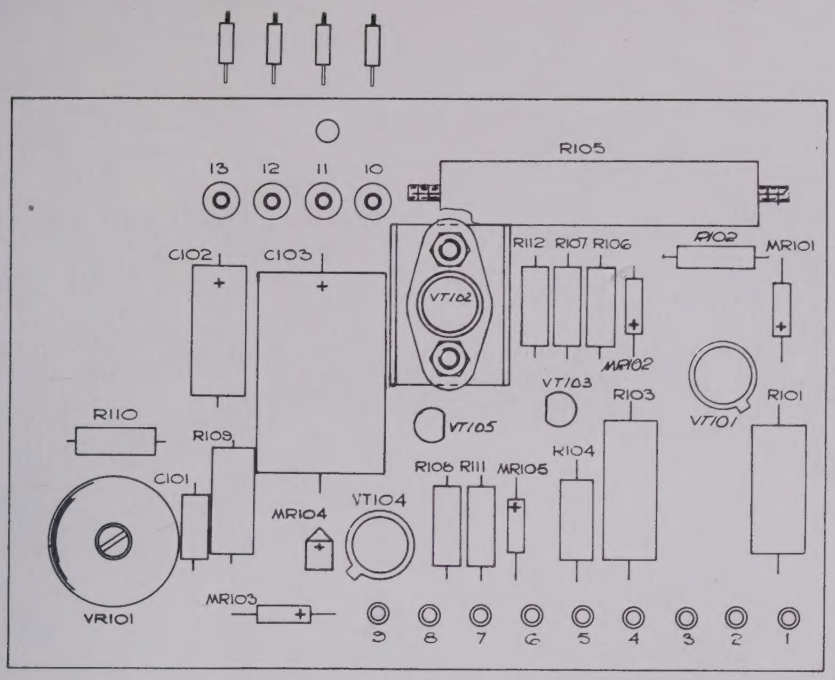
* Used on 441/442 only ** Used on 461/462 only

\+ Used on 441/461 only ++ Used on 442/462 only

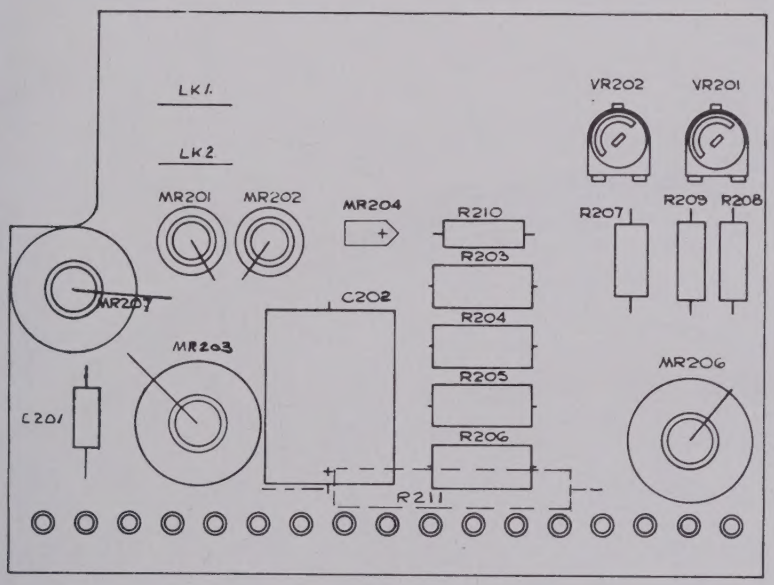


NOTE: 44 VOLT TAPPINGS ARE USED ON 440 SERIES ONLY

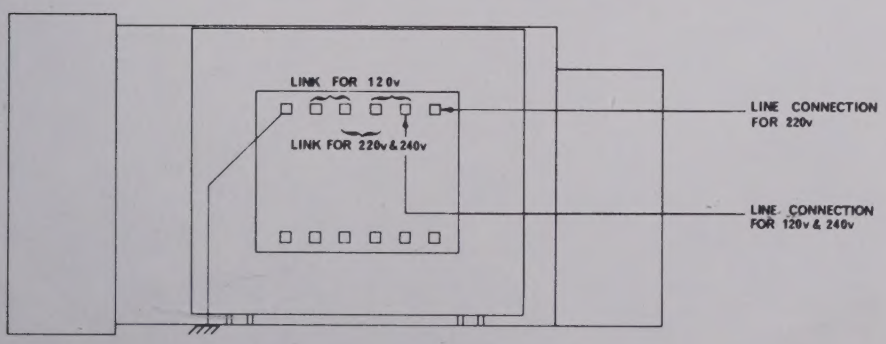
Circuit Diagram



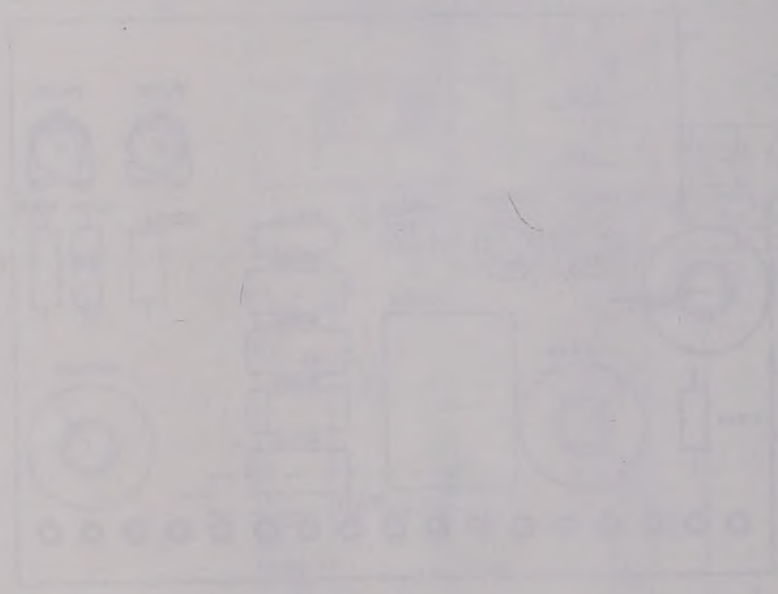
Component Board Layout - Amplifier Board

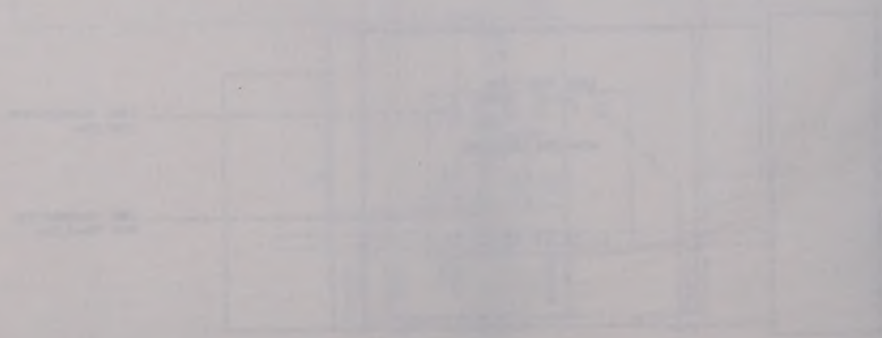


Component Board Layout - Rectifier Board



Power Supply Connections





MP MASTER
MA24531